LOCAL REINFORCEMENT TITANIUM CARBIDE TIC TYPE MANUFACTURED IN METHOD OF MOULD CAVITY PREPARATION USING 3D PRINTING

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Abstract

The article presents the way of improving usable properties of cast irons by producing titanate coats in founding process, introducing titanium insert directly before pouring molten metal. It is presented an innovative way to use 3D technology applying SLS method in order to obtain local reinforcement of cast iron. The object of studies was a material consisting of two fundamental parts: bearing part - cast iron, and working part represented by titanic modular insert. The article presents detailed geometry of the insert as well as the micro observation on light and scaning microscope. In addition, micro analysis and mapping of the permanent joints between two materials was executed, and also microhardness and wear resistance were examined. On the basic of obtained results, the presence of titanium carbides on the boundry cast iron- titanium insert was affirmed. Their dimensions and distribution were irregular in the volume of the material. Moreover, a local reinforcement of examined material was observed, as evidence by increase of wear resistance and microhardness compared to basic material.

Keywords: Grey cast iron; 3D printing insert; titanium; hardness; abrasive wear resistance

1. INTRODUCTION

Composite materials considered as combination of matrix and reinforcement represent one of the group of engineering materials. Matrix keeps reinforcement in a desired orientation, while reinforcement fortifies matrix in terms of stiffness and strength. As a result of combining process of those constituents, characterizing by significantly different properties, a brand new material with superior features compared to individual components is obtained. Constant growth of requirements relative to laden construction, particularly in aviation or automotive industry, forces the application of light, resistant and reliable materials, such as composites. It leads to intensive research on the development and constant improvement of those materials, at level of chemical composition as well as manufacturing technology [1-3].

The worth mentioning way of manufacturing layered materials and composites is the method of mould cavity preparation. The big advantage of this technology is that it is possible to enrich the surface of casting directly in cast process, averting cracks in heat affected zone. The insert, in a form of steel plate or metallic or ceramics powder, is placed in the mould cavity, followed by pouring molten metal, usually cast steel or cast iron. Correct preparation of the mould is an important factor to obtain a cast with desired properties, and relies on placing an insert in such place of the mould, where composite surface layer is expected. As a consequence of reaction between the insert and liquid metal, a composite surface layer rich in desired carbides is obtained [4-10].

The composite being an object of this paper, is a combination of grey cast iron (matrix) and the titanate insert (reinforcement), innovation of which consisted of manufacturing method. The insert was prepared using 3D printing based on SLS (selective laser sintering) method. It is an additive manufacturing technique that uses high power-density laser to sinter metallic powders together into a solid 3D-dimentinal part. This paper presents an analysis of a casting with scaffold insert with clearly defined overall dimensions and shape [11 - 13].

2. RANGE OF STUDIES

The main aim of investigation was to manufacture a cast with a scaffold insert using mould cavity preparation method. The insert was carried out in SLS method from pure Ti powder. Its weight does not exceed 5 % of the weight of the whole cast. The geometry of the insert is presented in **Figure 1a**. Scaffold was made by connecting rods of circular cross-section, arranged vertically and horizontally. Dimensions of external diameter (R_e) of rods is 1-5 mm and internal diameter (R_i) of rods is 50-90 % Re. The distance between connecting rods is 100-150 % of R_e. Dimensions of the insert are: 50x15x15 mm (**Figure 1b**) [14].

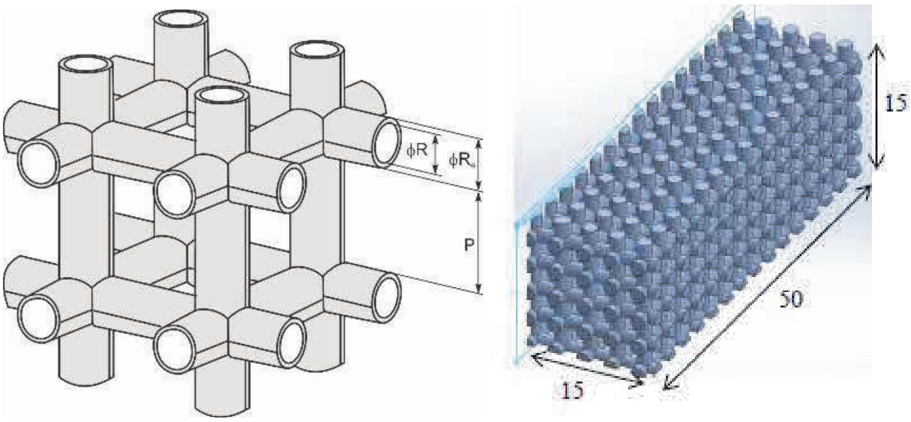

Figure 1 (a) Scheme of example cell of scaffold insert, (b) External dimensions of the insert

The insert was placed horizontally in the mould cavity and poured by molten grey cast iron with flake graphite at the temperature of 1,500 °C.

The next step provided metallographic examinations on light microscope Nikon and scanning electron microscope PhenomProX. Microhardness measurement was executed using load 10N with use of microhardness tester FUTURE-TECH. Abrasive wear resistance researches according to [15, 16] was also carried out. The speed of disk with the sample was 150 rpm and the speed of rotation of counterspecimen (abrasive paper from SiC) was 400 rpm.

3. RESULTS OF STUDIES

As it is seen in cross-section of the casting(**Figure 2**), titanium insert was partially dissolved in grey cast iron matrix, as consequence of which it was obtain a local reinforcement of the casting. Degree of dissolving of scaffold insert depends of pouring temperature which is the main parameter of casting process.

Figure 2 Cross-section of the casting (macrostructure)

In **Figure 3** microstructure of surface layer of obtained casting is presented. Reaction between liquid grey cast iron solidified in the mould and Ti insert provides that in high temperature zone, the atoms of carbon are set in octahedral interstice of titanium atoms what is accompanied by the precipitations of carbides. Thickness of obtained surface layer is irregular- concentration of carbides decreases with increasing distance from the insert.

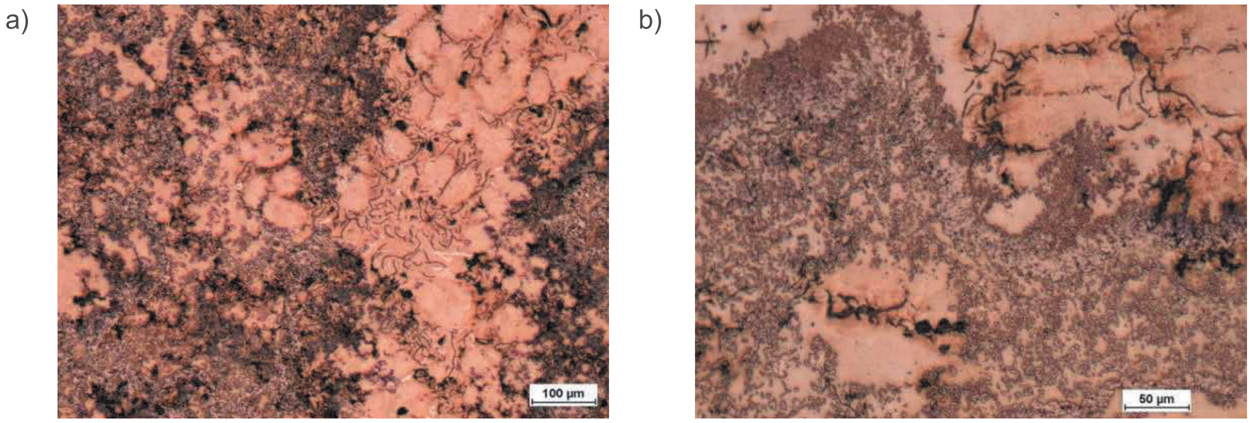

Figure 3 Microstructure of surface layer of casting reinforced by Ti insert, etch. Nital, mag: (a) 100x., (b) 200x., LOM

Metallographic examination affirmed that in each reinforced layer there are two areas i.e. internal with small amount of titanium carbides (**Figure 4a**) and external with large amount of titanium carbides (**Figure 5**). The internal area was created in the empty inside of the rod. Whereas the external layer was created in result of reaction between liquid cast iron and wall of rod. Pointwise EDS analysis, carried out in point selected from **Figure 4a**, affirmed that the carbides are mostly of the type TiC (**Table 1**). Titanium carbides have a very good connection to grey cast iron matrix and it can be considered that obtained surface layer is in the form of an in situ composite (**Figures 4 and 5**). They have different shapes and sizes (from 2 to 8 µm), as shows **Figure 6**.

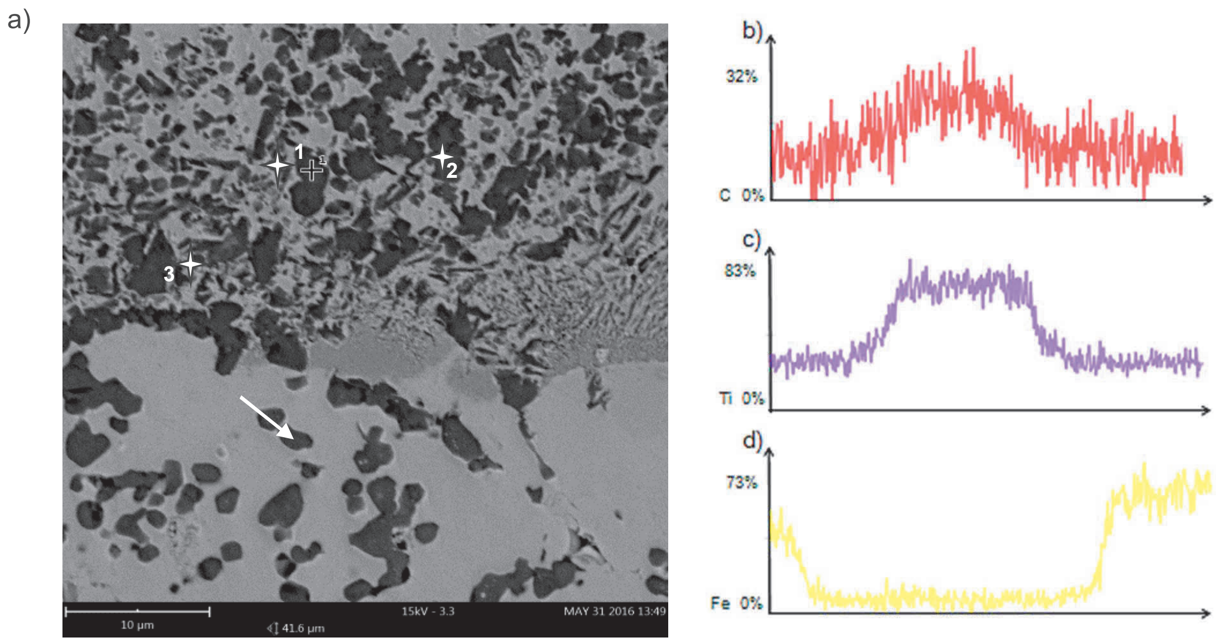

Figure 4 Linear EDS analysis of selected titanium carbide in pearlitic matrix in surface layer of casting: a) measurement area, b) distribution of C, c) distribution of Ti, d) distribution of Fe

Table 1 Pointwise EDS analysis (number of measuring points as in **Figure 4a**)

No	Ti %		C %		Fe %	
	atomic	weight	atomic	weight	atomic	weight
1	46.08	74.57	51.54	20.93	2.38	4.51
2	45.57	73.65	51.54	20.92	2.89	5.45
3	38.54	69.54	59.43	27.01	1.63	3.42

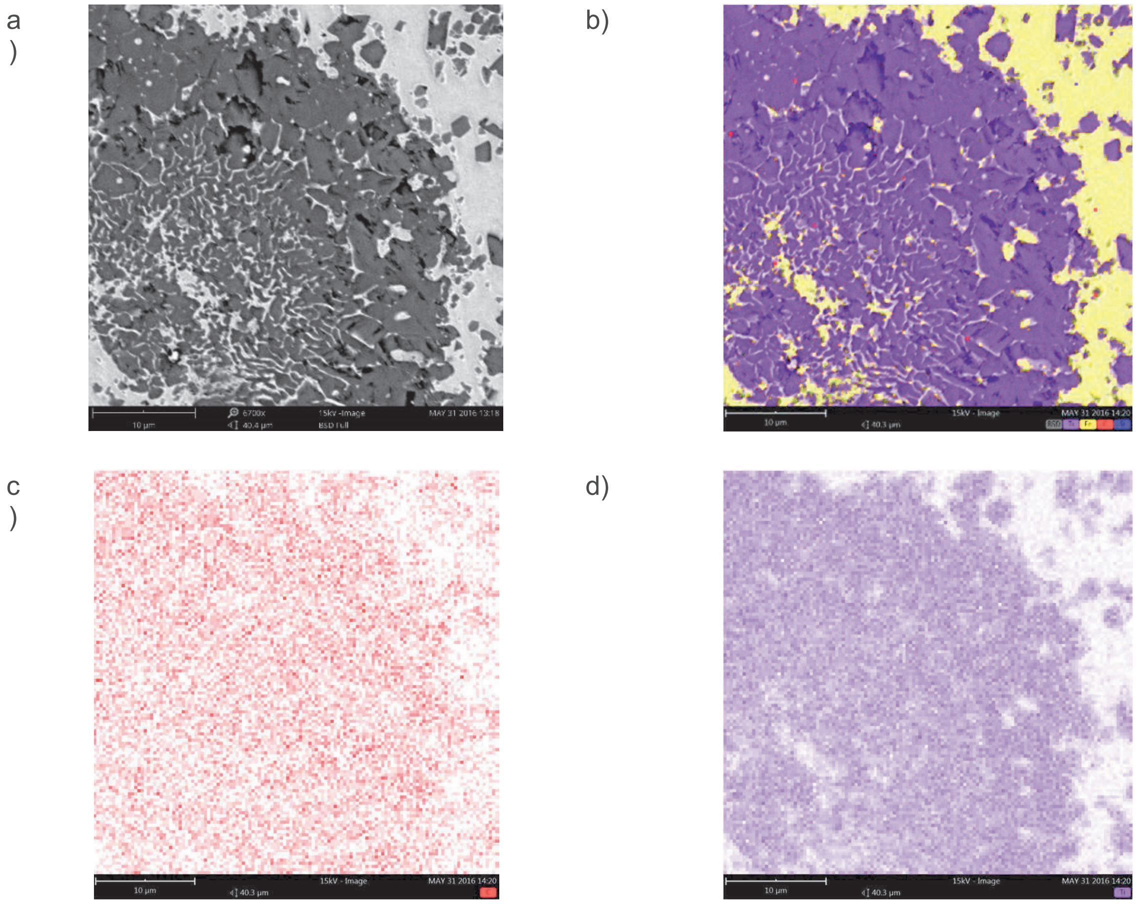

Figure 5 Mapping of selected structure:(a) measurement area, (b) distribution of all elements, (c) distribution of C, (d) distribution of Ti

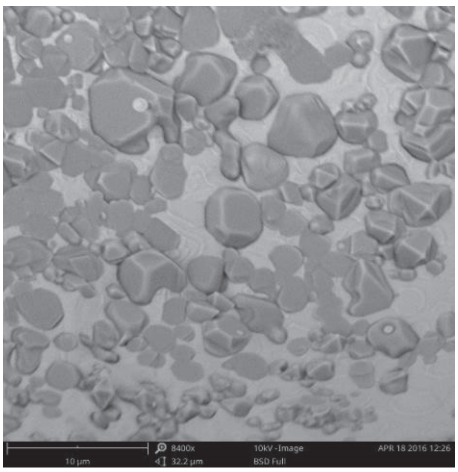

Figure 6 Exemplary titanium carbides

On the basic of the results of microhardness and wear resistance measurement it was affirmed, that the presence of TiC affects on strenght properties of the material. **Table 2** presents the results of microhardness measurement executed among the line indicated in **Figure 7**. Hardness depends on carbides' concentration. In the area with small amout of TiC, the measurement considered matrix material, and the value of microhardness was lower (approx. 500 μHV). The area with big concentration of carbides has hardness approx. 800 μHV.

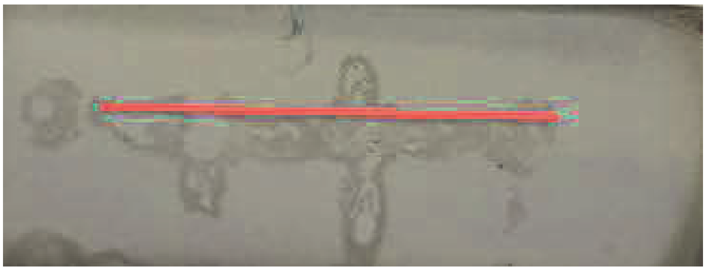

Figure 7 Measurement area of microhardness

Table 2 Results of microhardness measurement

No	Hardness, μHV									
1-10	568	832	862	481	550	688	508	533	522	696
11-20	785	550	563	862	624	729	754	628	703	635
21-29	540	863	689	598	633	740	491	724	697	
average: 657										

Such high hardness influenced on good abbrasive properties. The results presented in **Table 3** affirmed that casting composite has the lowest mass decrement during examination of wear resistance measurement compared to matrix material (grey cast iron) and chromium cast iron contains 3 % wt. of C and 18 % wt. of Cr at hardness 597 μHV and hardened low-alloyed steel contains 0.3 % wt. of C and 2 % wt. of Cr at hardness 440 μHV.

Table 3 Results of wear resistance measurement

Material	Mass decrement, g					Average mass decrement, g
casting composite	0.012	0.021	0.013	0.014	0.014	0.012
chromium cast iron	0.043	0.034	0.031	0.061	0.062	0.044
low alloyed steel	0.092	0.053	0.061	0.082	0.071	0.070
cast iron	0.262	0.201	0.203	0.192	0.281	0.226

4. CONCLUSIONS

The following conclusions were couched on the grounds of conducted research:

1) It is possible to reinforce surface layer of the grey cast iron casting by using 3D printing scaffold insert in the method of mould cavity preparation.
2) Reaction between pure Ti insert and liquid cast iron guarantees to obtain titanium carbides, mainly TiC in microstructure of surface layer, which increases hardness and wear resistance of casting.
3) The usable properties of composite surface layer obtained in result of use of the method presented in the paper, strongly depend of dimensions of scaffold insert, mainly parameters R_e and R_i.

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